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# BIOTECHNOLOGY IN AFRICAN AGRICULTURAL RESEARCH: OPPORTUNITIES FOR DONOR ORGANIZATIONS

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*Agricultural research in Africa is generally very dependent on financial support from donor agencies and international lending organizations such as the World Bank. This is evident in past ISNAR work, and recent studies carried out in Zimbabwe and Kenya confirm it is even more the case for research in agricultural biotechnology. Donor agencies considering investing in agricultural biotechnology research in Africa should carefully determine where the most pressing needs and current opportunities are.*

*There is, however, little information available on the development of agricultural biotechnology in Africa, and this constrains donor agencies in strategically directing their funding. For this reason, the Rockefeller Foundation, one of the leading donors supporting agricultural biotechnology, commissioned several assessment studies of regions and crops that may be considered for increased support. In May 1998 the Foundation requested ISNAR to analyze the needs and opportunities for greater investment in biotechnology research concerning African crops. That same year, ISNAR was also requested to support the planning process for a new donor initiative from Sweden on biotechnology capacity building in four East African countries, and to assist the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) in developing its initiative on biotechnology and biosafety. These concurring requests and increased attention for biotechnology in Africa enhance the relevance of our study for the Rockefeller Foundation.*

*This Briefing Paper presents the main findings and recommendations of the report to the Rockefeller Foundation, and will also be of interest to other donor organizations, policymakers, and research directors responsible for agricultural research in Africa. The report is based on a survey carried out by ISNAR, in close collaboration with the International Institute of Tropical Agriculture (IITA) and fifteen collaborators from national and international organizations, that yielded information on fifty African research institutes in nine countries, and on a selected group of relevant international institutes and programs.*

*The survey showed that a wide range of biotechnology tools is available for application in crop improvement programs, especially those related to tissue culture and genetic markers. Genetic engineering is not widely applied, and is primarily in the experimental phase. Research capacities in the nine countries are severely limited — with some exceptions — and too often donor-dependent. Resources are spread over a wide range of crops, and emphasize the "low tech" applications of biotechnology. Recommendations therefore stress that donor support to agricultural biotechnology should focus on a limited number of priority crops, and involve the institutes with the capacity to undertake advanced research. Technical assistance on management aspects of biotechnology, such as instituting biosafety mechanisms, should be an integral component of any new initiative.*

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## Purpose and Objectives

The purpose of the study for the Rockefeller Foundation was to assess the needs and opportunities for greater investment in biotechnology research involving African crops. It was decided to focus on a limited number of countries in Sub-Saharan Africa and a limited number of crops. Nine countries were included in the study: Ethiopia, Kenya and Uganda in East Africa; Malawi, South Africa and Zimbabwe in Southern Africa; Cameroon, Ghana and Nigeria in West Africa. Six crops were selected as target crops: banana / plantain, cassava, cowpea, maize, sorghum and yams. The six crops were selected based on their importance to local food production in the target countries, their position in national and international agricultural research programs, and the interests of the donor agency commissioning the study. ISNAR conducted the survey in the target countries from June to September 1998. A first version of the synthesis report was submitted to the Rockefeller Foundation in October 1998, and circulated for review among the study collaborators in November-December 1998. The final report to the Rockefeller Foundation was submitted in January 1999. The main findings are presented in this Briefing Paper, which has the following objectives.

- To provide a synthesis of the study's findings on national and international collaborative crop research activities that involve applications of biotechnology.
- To review current progress with regard to the development of important biotechnology tools and their application in crop improvement programs.
- To identify major crop production constraints that are presently being addressed by agricultural biotechnology research in Africa.

## Context for Agricultural Biotechnology in Africa

Although much of Africa's population still depends directly on agriculture, most of the growth in income, modest as it is, has occurred in the nonagricultural sector. Agricultural GDP per capita throughout the region has fallen by 32 % since 1961. The agricultural production picture has recently shown a little more promise, with the growth in agricultural GDP keeping pace with the growth in population.[1]

While the factors affecting growth and productivity in agriculture are many, there is general agreement that investing in a functioning agricultural R&D system is a necessary component of a successful development strategy. In Africa this principle spurred a rapid increase in the number of agricultural researchers. The total number of full-time-equivalent researchers grew fourfold in the period 1961-1991, and their levels of formal training rose as well. However, real agricultural research expenditures began to shrink in the 1980s. The result is that research spending per scientist in 1991 averaged about 66 % of the 1961 level. This downward trend also reflects the changing composition of the scientific workforce, from predominantly well-paid expatriates — accounting for 11% of the researchers working in national agencies throughout sub-Saharan Africa (excluding South Africa) in 1991, down dramatically from 90% in the early 1960s — to local staff. Only Botswana, South Africa, Swaziland, and Zimbabwe spent more per scientist in 1991 than they had three decades earlier.

The decrease in national government support for agricultural research has also led to an increased dependence on donor funding. In 1991, the share of donor funds in financing public agricultural research amounted to 45%.

Another recent ISNAR study[2] shows that most countries in sub-Saharan Africa have developed an agricultural research plan, although the plans vary significantly by type and content. That study shows that the six target crops included in the present study are generally regarded as priority crops, especially maize, sorghum, and cassava. Other high-priority food crops include millets, rice, sweet potato, groundnuts, beans, and vegetables.

### National Programs in Agricultural Biotechnology

Many African governments have set up special governance and capacity-building mechanisms to advance the application of modern biotechnology in their countries. These cover a broad range: from establishing advisory committees to developing specific programs for research and training activities to establishing specialized biotechnology research institutes. It should be noted that these initiatives are primarily supported by donor agency funds.

Despite a systematic trend towards adopting selected biotechnology techniques and processes, the uptake of biotechnology in Africa has been slow. Many factors contribute to this in each of the different countries. Research in Africa has to be conducted under circumstances constrained not only by financial limitations (see box 1) but also by limited national capacities, policy directions, and the regulatory environment. To date, few field trials of transgenic crops have taken place in Sub-Sahara Africa, and these have been primarily in South Africa.[3]

1 Information in this section was extracted from Pardey, Roseboom and Beintema (1996).
2 Hambly and Sethswaelo (1997)
3 See James, C. (1997).

## International Programs for Biotechnology in Africa

International collaborative efforts are a major source of support for research and training in agricultural biotechnology in African countries. Since 1985 a wide range of international initiatives has been undertaken, primarily supported by multilateral and bilateral donor agencies. Komen (1997) gives an overview of these along with their collaborative activities in Africa. For the present study, we conducted an update of relevant international activities in the target countries. The results are included in Section V below.

On the regional and sub-regional level the number of programs concerning biotechnology in Africa are very limited. The activities of African biotechnology networks are summarized in Brink et al. (1998). While this overview is encouraging, these networks appear to play only a modest role in actual capacity building. The situation may change because of the recent decision by the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) to initiate a regional program on biotechnology. ASARECA is currently assessing the role it should play in biotechnology in the region, taking into account the limited capacity for biotechnology in most of its member countries. Similarly, an Africa branch for the Cassava Biotechnology Network (CBN-A) was recently established in Uganda, and this will strengthen regional efforts in advanced cassava research.

### Box 1. National Investments in Agricultural Biotechnology: The Case of Kenya

Kenya can be taken as an example that illustrates the development of agricultural biotechnology in African countries. A recent review of human and financial resources available for agricultural biotechnology R&D concludes the following:

- Although expenditure on agricultural biotechnology research has grown annually, its share of total agricultural research expenditures in Kenya is marginal, 2.3% on average, and declined in the period 1989-1996.
- In 1989-1996, donor contributions constituted the primary source of funding for agricultural biotechnology research. On average, they represented about 65% of the total expenditure for agricultural biotechnology research.
- The public sector accounted for 94% of research expenditures in 1989-1996. The share of the private sector was 6%.
- In the same period, the number of researchers grew faster than research expenditures. This has led to a significant decline in expenditures per researcher: in nominal terms from US$ 30,000 in 1989 to US$ 18,000 in 1996.

Donor agencies play a major role in the development of agricultural biotechnology in Kenya. Through a bilateral donor initiative, the Kenya Agricultural Biotechnology Platform (KABP) was set up as part of the Special Program Biotechnology and Development, supported by the Netherlands. KABP advises the Kenyan government on the development of agricultural biotechnology in the country. KABP manages the Kenya component of the Special Program, which has a budget for R&D projects of around US$ 3 million for the period 1997-2001. Under phase II (1997-2001) of the National Agricultural Research Project (NARP) – through which a consortium of donors, convened by the World Bank, support the research programs of the Kenya Agricultural Research Institute (KARI) – around US$ 750,000 will become available for agricultural biotechnology.

*Source:* Wafula and Falconi (1998)

# Survey Findings: National R&D in Agricultural Biotechnology

A total of fifty national research institutes from nine different countries was included in the survey[4]: Cameroon – completed questionnaires received from 2 research institutes; Ethiopia – 5; Ghana – 3; Kenya – 6; Malawi – 8; Nigeria – 10; South Africa – 6; Uganda – 3; Zimbabwe – 6. The survey identified a total of 230 distinct research activities, covering a wide range of crops. While the respondents were asked to focus on the six target crops, no less than a total of 45 crops were included in their responses. Table 1 provides an aggregate overview of the crops covered by the survey and their importance relative to each other. The study's target crops are involved in 47% of the activities identified (107 research activities out of a total of 230). Important non-target crops are export crops such as fruits and vegetables; coffee and other cash crops such as cocoa, tea and cotton; other root crops such as potato and sweet potato; other cereals such as teff, millet, and barley; and other legumes such as groundnut and soybean.

Responses to the survey may have been influenced by the interest we showed in the target crops. However, it should be noted that these crops are involved in less than half of the research activities that were reported. This suggests that resources are spread thinly, with only limited attention paid to major food crops.

### Techniques Applied

The 230 research activities involve a wide range of biotechnology applications. In the survey, applications were categorized as follows: Tissue culture, Genetic engineering, Genetic markers, Diagnostics, and Microbiology. Each category includes details on the specific techniques involved.

4 The survey instrument requested information on: the resources currently available for research in agricultural biotechnology (financial resources, human resources, equipment); details concerning current research activities (crops involved, objectives, techniques applied); the IARCs and other advanced research institutes they collaborate with; future plans and constraints to research progress.

Table 1 provides an aggregate analysis of the techniques that were reported as being applied to each crop. From this we see that there is a strong emphasis on applying tissue culture techniques: tissue culture, primarily micropropagation, is involved in 110 research activities, or 48 % of the total. The table shows the much smaller role played by diagnostics and genetic markers. In addition, a smagents to combat insect pests. Genetic engineering is involved in 33 research activities, and these are primarily carried out in South African research institutes. Maize stands out as the crop that is most often subject to advanced biotechnology applications such as genetic markers and genetic engineering.

## Production Constraints Targeted

Crop production in African countries is usually constrained by incidences of pests and diseases, poor soil conditions, and abiotic stress factors such as drought and heat. Respondents to the questionnaire were asked to specifically indicate the crop production constraint(s) that their research activities target.[5] Our analysis of their responses indicates that the main constraints being targeted by biotechnology are:

*Banana/plantain:* limited availability of disease-free planting material, fungal diseases (Black sigatoka, fusarium wilt)
*Cassava:* limited availability of disease-free planting material, bacterial blight, African cassava mosaic virus
*Cowpea:* cowpea mosaic virus, pod borers
*Maize:* cob rot, drought, borers
*Sorghum:* Striga (witchweed)
*Yams:* limited availability of disease-free planting material

## Assessing National Capacity

The survey requested the fifty national research institutes to supply recent data on available resources for research in terms of funding, human resources, and infrastructure. Analysis of the data indicates that resources available for research in the area of agricultural biotechnology are scarce and spread over a wide range of research activities and target crops. However, there are notable exceptions to the overall picture. A limited number of national research institutes have the

**Table 1. Use of Biotechnology in 50 African Research Institutes**

| Crop | Reported number of applications for specific techniques | | | | | |
|---|---|---|---|---|---|---|
| | Microbiology | Tissue culture | Diagnostics | Genetic markers | Genetic engineering | TOTAL |
| **CEREALS** | | | | | | |
| **Maize** | 1 | 1 | 3 | 9 | 9 | 23 |
| **Sorghum** | 2 | 2 | | 3 | 2 | 9 |
| **Other cereals** | 1 | 4 | | 4 | 3 | 12 |
| **ROOT CROPS** | | | | | | |
| **Cassava** | 4 | 14 | 3 | 2 | 4 | 27 |
| **Yams** | 1 | 13 | 2 | | | 16 |
| **Sweet potato** | | 12 | 1 | | 2 | 15 |
| **Potato** | | 5 | 1 | 1 | 2 | 9 |
| **FRUITS & VEGETABLES** | | | | | | |
| **Banana/plantain** | 3 | 14 | 4 | | | 21 |
| **Citrus** | 2 | 3 | 4 | 2 | 1 | 12 |
| **Other fruits & vegetables** | | 9 | 2 | | 4 | 15 |
| **LEGUMES** | | | | | | |
| **Cowpea** | 3 | 2 | 2 | 3 | 1 | 11 |
| **Other legumes** | 3 | | 3 | 1 | 3 | 10 |
| **CASH CROPS** | | | | | | |
| **Coffee** | | 5 | 2 | | | 7 |
| **Other cash crops** | 1 | 17 | 2 | 6 | | 26 |
| **FORESTRY** | | 5 | | 1 | | 6 |
| **OTHERS** | 3 | 4 | 2 | | 2 | 11 |
| **TOTAL** | 24 | 110 | 31 | 32 | 33 | 230 |

5 Specific production constraints were grouped into seven major categories: *Propagation* – the availability of (disease-free) planting material; *General* – technology development or germplasm conservation; *Disease* – fungal and bacterial diseases; *Virus* – plant viruses; Insect – insects; *Abiotic* – stress factors such as drought or nitrogen deficiency; *Quality* – quality factors such as yield or nutritional value; and *Other* (e.g., herbicide tolerance).

human and financial resources, as well as the laboratory facilities, to undertake research in molecular biology. These are primarily found in South Africa, where such advanced institutes have also assumed a regional role in R&D collaboration and training. In the other countries included in the study, facilities for molecular biology are very limited but may become available when current expansion plans are completed in institutes in Ethiopia, Kenya, and Zimbabwe.

Facilities for tissue culture and micropropagation are more widely available and may be a starting point for developing more advanced programs in plant biotechnology. Micropropagation units and tissue culture laboratories are found in all countries included in the study.

## International Collaborative R&D

As mentioned in section II above, and confirmed by the respondents from the national institutes, most advanced biotechnology applications are undertaken as part of international collaborative programs. In order to obtain an overview of these research activities in Africa, and to identify advanced research institutes conducting relevant research, survey forms were sent to a limited number of international research institutes and programs. We received information back from seven international agencies that have collaborative biotechnology R&D activities involving the study's target crops and countries.[6]

### International Collaborative Research: Crops and Constraints

With this component of the survey we collected information on 94 research activities. We were interested in the objectives and techniques involved as well as the collaborative efforts between African and advanced research institutes.

Table 2 gives an overview of the international research activities being conducted on the target crops. Maize and cassava come out as the two most important, just as they do in the overview of the national research activities

**Table 2. Use of Biotechnology in seven International Research Programs**

| Crop | Reported number of applications for specific techniques | | | | | |
|---|---|---|---|---|---|---|
| | Micro-biology | Tissue culture | Diagnostics | Genetic markers | Genetic engineering | TOTAL |
| **CEREALS** | | | | | | |
| **Maize** | | | | 14 | 3 | 17 |
| **Sorghum** | | | | 11 | 2 | 13 |
| **Pearl millet** | | | | 4 | | 4 |
| **Other cereals** | | | | 2 | | 2 |
| **ROOT CROPS** | | | | | | |
| **Cassava** | 2 | 2 | 1 | 9 | 2 | 16 |
| **Yams** | | 1 | | 2 | 2 | 5 |
| **Other root crops** | | | | | 2 | 2 |
| **FRUITS & VEGETABLES** | | | | | | |
| **Banana/plantain** | | 3 | 2 | 4 | 2 | 11 |
| **Other fruits & vegetables** | | | | | 1 | 1 |
| **LEGUMES** | | | | | | |
| **Bean** | | | 4 | 5 | | 9 |
| **Cowpea** | 1 | | | 2 | 3 | 6 |
| **Pigeonpea** | | | | 2 | 2 | 4 |
| **Other legumes** | 1 | | | 1 | 2 | 4 |
| **TOTAL** | 4 | 6 | 7 | 56 | 21 | 94 |

6 The seven responding agencies were: The Agricultural Biotechnology Support Project (ABSP), the Bean-Cowpea Collaborative Research Support Program, the International Center for Tropical Agriculture (CIAT), the International Maize and Wheat Improvement Center (CIMMYT), the *Centre de coopération internationale en recherche agronomique pour le développement* (CIRAD), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Institute for Tropical Agriculture (IITA).

Production constraints were examined by grouping the research activities into the same seven categories used on the national level. Compared to the national research activities, there are a very limited number of activities addressing the propagation of disease-free planting material. Instead, a stronger emphasis is placed on work aimed at developing plant resistance to insect pests, viruses, and bacterial or fungal diseases. Specifically, the major production constraints addressed for the study's target crops are:

*Banana/plantain:* streak virus, Black sigatoka
*Cassava:* bacterial blight, mosaic viruses
*Cowpea:* weevils, borers
*Maize:* borers, streak virus, drought, Striga
*Sorghum:* head bug, stem borer
*Yams:* mosaic virus, nematodes.

### International Collaborative Research: Techniques Applied

We put the international research activities into the same technology categories as those used on the national level (see Table 1). Table 2 shows the strong emphasis in these programs on applying genetic markers: they are applied in almost 60 % of the research activities identified. This is followed by research involving applications of genetic engineering (22 %). The aggregate overviews of national and international research activities point to a high complementarity between them. While national institutes concentrate on tissue culture and micropropagation, the international programs are more advanced in molecular biology applications. This appears to be a rational division of labor, and the challenge will be to transfer the capacity to apply more advanced techniques to the national institutes.

As is the case in the national research activities, the number of research activities involving genetic engineering is quite low, two or three for each target crop, and these are reported to be primarily in the experimental stages. The use of genetic markers is widespread and routinely applied for all target crops. The genetic-marker techniques most often used are RFLP[7], AFLP[8] and microsatellite markers[9]. They are primarily applied to identify sources of resistance against diseases (in 14 research activities), viruses (10) and insects (9), and for general purposes such as germplasm characterization (15).

### Advanced Organizations involved in Collaborative Research

The international research programs collaborate with a range of different types of research institutes in developed countries that are developing and applying advanced biotechnology tools to tropical crops. In this way they provide additional opportunities for African research institutes that wish to strengthen their capacity in agricultural biotechnology.

In the survey of national research institutes, respondents were also requested to list international research institutes and other advanced research institutes with whom they collaborate. Linkages with one or more CGIAR institutes were indicated in 25 % of the national research activities reported, and collaboration with other advanced institutes in 20 %. In comparison, 76 % of the reported international collaborative research activities involve one or more advanced partner research institute.

A number of respondents outside South Africa reported collaboration with South African institutes as collaboration with advanced research institutes. This points to a potential regional role they can play in developing research capacity in the study's target countries.

## Progress in Establishing Biosafety Regulations

A range of biotechnology-based products can be expected to be generated from international collaborative programs, from the international private sector, or from advanced national programs. Some of these products, for example transgenic plants, require biosafety review. The absence of a functioning biosafety review mechanism may be an obstacle to the diffusion of the products from modern biotechnology. For this reason we included a review of the biosafety systems in the target countries in our study for the Rockefeller Foundation.

Establishing a system for biosafety review is a complex undertaking. It includes not only the formulation and adoption of safety guidelines and the establishment of national and institutional biosafety committees, but also ensuring the availability of infrastructure for contained and large-scale field testing of genetically-modified organisms. Of the countries included in this study, Kenya, Nigeria, South Africa, Uganda, and Zimbabwe have taken steps to develop biosafety review mechanisms, and the process has advanced most in South Africa. Table 3 summarizes the status of biosafety devel-

7 Restriction fragment length polymorphism (RFLP): Differing patterns of DNA fragments that distinguish individuals, produced by cutting DNA with restriction enzymes and analyzing the size of the fragments; can be used as a tool in breeding programs to monitor the inheritance of genes associated with a particular fragment.

8 Amplified fragment length polymorphism (AFLP): A DNA fingerprinting technique that detects distinguishing restriction fragments by means of PCR (polymerase chain reaction) amplification; can be applied in genetic studies, such as the analysis of germplasm collections or the construction of genetic marker maps.

9 Microsatellite markers: a PCR-based marker system that requires only small amounts of DNA, usually displays a higher variability than other marker systems, and can easily be automated.

opments in these five countries. In the other four countries – Cameroon, Ethiopia, Ghana and Malawi – no formal biosafety review mechanisms had been established as of 1998. In these countries initial steps have now been taken to discuss biosafety issues among the various national agencies involved.

Donor-supported technical assistance for biosafety development in Africa has been quite extensive, mainly in the form of workshops and training programs. Recently, however, this has appeared to be decreasing. For example, the Regional Biosafety Focal Point based in Harare was established with support from the government of the Netherlands in 1993, but funding stopped in 1997. In 1998, some new initiatives were started regarding biosafety in Africa including (1) the East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development (BIO-EARN), supported by the government of Sweden, (2) a Pilot Biosafety Enabling Activity, supported by the Global Environment Facility, to develop national biosafety guidelines in countries such as Cameroon, Kenya, Malawi and Uganda, and (3) ASARECA, the Association for Strengthening Agricultural Research in East and Central Africa, which is assessing the feasibility of a regional initiative on biotechnology for agricultural research that will also cover biosafety issues.

**Table 3. Status of Biosafety in Selected African Countries (January 1999)**

| Stage | Kenya | South Africa | Zimbabwe | Nigeria | Uganda |
|---|---|---|---|---|---|
| Writing Team Assembled | Yes | Yes | Yes | Yes | Yes |
| Guidelines Drafted | Yes | Yes | Yes | Yes | Yes |
| Guidelines Promulgated | Yes | Yes | Yes | No | No |
| NBC Established | Yes | Yes | Yes | No | Yes |
| Guidelines Implemented | Yes | Yes | No | Yes | No |
| IBC Established | Yes | Yes | No | No | No |
| Reviewers Trained | No | Yes | No | No | No |
| Applications Received | Yes | Yes | Yes | No | No |
| Approvals Given | No | Yes | No | No | No |
| Greenhouse Experiments Conducted | No | Yes | No | No | No |
| Field Tests Conducted | No | Yes | No | No | No |

*Source:* Data provided by Pat Traynor, Information Systems for Biotechnology, Virginia Polytechnic and State University

## Conclusions and Recommendations

Based on the literature review and the findings of the survey concerning national and international research activities, the following conclusions are drawn:

- Applications of agricultural biotechnology are being used to address some of the major crop production constraints in Africa. In particular, biotechnology provides tools that enhance ongoing crop improvement programs. This especially applies to genetic markers that improve the efficiency of plant breeding.
- Applications of biotechnology are slowly becoming part of mainstream agricultural research in African countries, but further advances in agricultural biotechnology are severely constrained by a lack of funds, skilled human resources, and equipment. Research and training in cellular biology for vegetatively propagated crops are now well established. Combined with disease diagnostics, this has contributed to the development of improved planting material for major crops.
- A wide range of biotechnology tools is already available for application in crop improvement programs, especially those related to tissue culture and micropropagation (used extensively in the national research programs) and genetic markers (through international collaborative research). Genetic engineering is much less widely applied, and is primarily in the experimental phase, due to the lack of appropriate research infrastructure and skilled scientific personnel.
- International institutes and international programs have developed good relations with strong African research institutes, and provide a bridge to advanced research institutes in Europe and the USA. Opportunities for collaborative research are provided by several CGIAR institutes, a number of international research programs, and advanced public research institutes in Europe and the US involved in international collaboration. Their activities address constraints similar to those targeted by the national research institutes, but they apply more advanced techniques. High complementarity exists between the research activities at the national and international level, providing a solid base for future initiatives.
- In general, national resources and capacities are severely limited and too often donor-dependent.

They are spread over a wide range of crops and resources, and emphasize the “low tech” applications of biotechnology. A few exceptions were identified where molecular biology research is taking place or will be initiated. Tissue culture and micropropagation units are found in all countries included in the study, and they can serve as a starting point for more advanced research.

- The absence of clear-cut and well-defined biosafety systems in most African countries may be an obstacle to the diffusion of the products from modern biotechnology to farmers’ fields.

The following recommendations are made for donor agencies:

- Any support to agricultural research, including agricultural biotechnology, should focus on a limited number of priority crops, clear objectives, and institutes with the capacity to undertake advanced research. This will avoid a further scattering of efforts.
- In any new donor initiative, the potential national and international partners should be consulted and involved at an early stage to better determine the actual needs and opportunities for future work. Collaboration with regional initiatives such as ASARECA’s biotechnology program should be actively sought. Strong national institutes should be supported to take up a regional role in research and training.
- Research and technical assistance on management aspects of biotechnology, such as biosafety, should be an integral component of any new initiative. The study shows that some African countries have taken initial steps to develop a biosafety review mechanism, but the infrastructure and human resources needed to evaluate and eventually conduct field trials are limited. This area needs further strengthening in order to evaluate the potential benefits and risks of applying advanced biotechnology.
- Agricultural research in general, and biotechnology in particular, is already heavily donor-dependent. National public and private investments should increase in order to make new initiatives sustainable. This may require special incentives for private-sector investments, the creation of a favorable policy environment for public-private collaboration, and the protection of intellectual property and proprietary technologies.

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